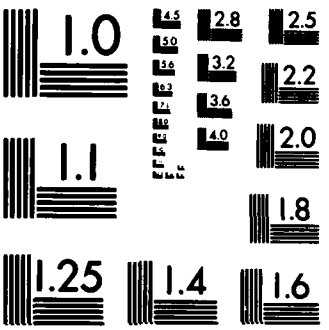
AD-A132 606 FAST OPTICAL POSITION-SENSITIVE DETECTOR FOR MCPHERSON ESCA-36..(U) AEROSPACE CORP EL SEGUNDO CA CHEMISTRY AND PHYSICS LAB P A BERTRAND ET AL. 01 JUN 83 1/1

UNCLASSIFIED TR-0083(3945-06)-3 SD-TR-83-40 F/G 14/2 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

REPORT SD-TR-83-40

(12)

Fast Optical Position-Sensitive Detector for McPherson ESCA-36

AD-A132 606

P. A. BERTRAND, W. J. KALINOWSKI,
L. E. TRIBBLE, and L. U. TOLENTINO
Chemistry and Physics Laboratory
Laboratory Operations
The Aerospace Corporation
El Segundo, Calif. 90245

1 June 1983

APPROVED FOR PUBLIC RELEASE;
DISTRIBUTION UNLIMITED

DTIC
ELECTE
SEP 2 0 1983
S
A

DTIC FILE COPY

Prepared for
SPACE DIVISION
AIR FORCE SYSTEMS COMMAND
Los Angeles Air Force Station
P.O. Box 92960, Worldway Postal Center
Los Angeles, Calif. 90009

This report was submitted by The Aerospace Corporation, El Segundo, CA 90245, under Contract No. F04701-82-C-0083 with the Space Division, Deputy for Technology, P.O. Box 92960, Worldway Postal Center, Los Angeles, CA 90009. It was reviewed and approved for The Aerospace Corporation by S. Feuerstein, Director, Chemistry and Physics Laboratory. 2nd Lt Ken R. Hasegawa, SD/YLV, was the project officer for the Mission-Oriented Investigation and Experimentation (MOIE) Program.

This report has been reviewed by the Public Affairs Office (PAS) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nationals.

This technical report has been reviewed and is approved for publication. Publication of this report does not constitute Air Force approval of the report's findings or conclusions. It is published only for the exchange and stimulation of ideas.

Ken R. Hasegawa, 2nd Lt, USAF
Project Office

Norman W. Lee, Jr., Colonel, USAF
Commander, Det 1, AFSTC

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER SD-TR-83-40	2. GOVT ACCESSION NO. AD-A132606	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) FAST OPTICAL POSITION-SENSITIVE DETECTOR FOR McPHERSON ESCA-36		5. TYPE OF REPORT & PERIOD COVERED 6. PERFORMING ORG. REPORT NUMBER TR-0083(3945-06)-3
7. AUTHOR(s) Patricia A. Bertrand, Walbert J. Kalinowski, Lewis E. Tribble, and Lucio U. Tolentino		8. CONTRACT OR GRANT NUMBER(s) F04701-82-C-0083
9. PERFORMING ORGANIZATION NAME AND ADDRESS The Aerospace Corporation El Segundo, Calif. 90245		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Space Division Air Force Systems Command Los Angeles, Calif. 90009		12. REPORT DATE 1 June 1983 13. NUMBER OF PAGES 17
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

ESCA
Position-Sensitive Detection
XPS
X-Ray Photoelectron Spectroscopy

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

An optical position-sensitive detection system was added to a McPherson ESCA-36 x-ray photoelectron spectrometer. The system contains a multichannel electron multiplier and vidicon TV camera and operates 250 times faster than the original single-channel electron multiplier.

DD FORM 1473 (FACSIMILE)

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

PREFACE

We would like to thank P. D. Fleischauer and G. W. Stupian for many helpful discussions.

Accession For
NTIS GRA&I ☒
DTIC TAB ☐
Unannounced ☐
Justification
By
Distribution/
Availability Codes
Dist | Avail and/or Special
A

CONTENTS

FAST OPTICAL POSITION-SENSITIVE DETECTOR
FOR McPHERSON ESCA-36..... 7

REFERENCES..... 17

FIGURES

1. Schematic Diagram of GCA/McPherson ESCA-36 with Optical Position-Sensitive Detector..... 8

2. Flow Diagram of Spectrometer-Control Program..... 10

3(a). Schematic Diagram of Interface Between Detector and Computer..... 11

3(b). Schematic Diagram of Interface Between Detector and Computer..... 12

4. Spectra with Equivalent Signal-to-Noise Ratio Taken Before and After Installation of Position-Sensitive Detector..... 15

5. Typical Spectra of 0.1 cm^{-2} HgCdTe Wafer..... 16

FAST OPTICAL POSITION-SENSITIVE DETECTOR FOR McPHERSON ESCA-36

X-ray photoelectron spectroscopy (XPS) is a valuable technique for surface analysis because it provides information about chemical oxidation states as well as elemental composition of the surface layers. A major drawback to XPS is the low count rate and consequent long periods of time needed for analysis. This requires stringent vacuum conditions and causes sample damage from long x-ray exposures. In recent years various multichannel detection systems using pulse-counting techniques have been applied to XPS spectrometers to increase the speed of analysis.[1-4] This note is a description of the addition of a time-integrating optical position-sensitive detection system to a GCA/McPherson ESCA-36 spectrometer. This new detection system operates approximately 250 times faster for equivalent signal-to-noise ratio than the original single-channel ESCA-36 multiplier.

A schematic diagram of the modified ESCA-36 spectrometer is given in Fig. 1. Photoelectrons emitted from the sample pass through a slit and a system of baffles, then enter a spherical-sector electrostatic analyzer. The electrons are dispersed in the field of the analyzer, which is given by[5]

$$V(r) = \left[\frac{V_2 - V_1}{\frac{1}{R_1} - \frac{1}{R_2}}\right]\left[\frac{1}{R_1} - \frac{1}{r}\right] + V_1$$

where r is the radial position of the electron, V_1 and V_2 are the potentials applied to the inner and outer spheres, respectively, and R_1 and R_2 are the radii of the spheres. Thus electrons exit the analyzer at different points along the exit aperture depending on their energy; this dispersion function

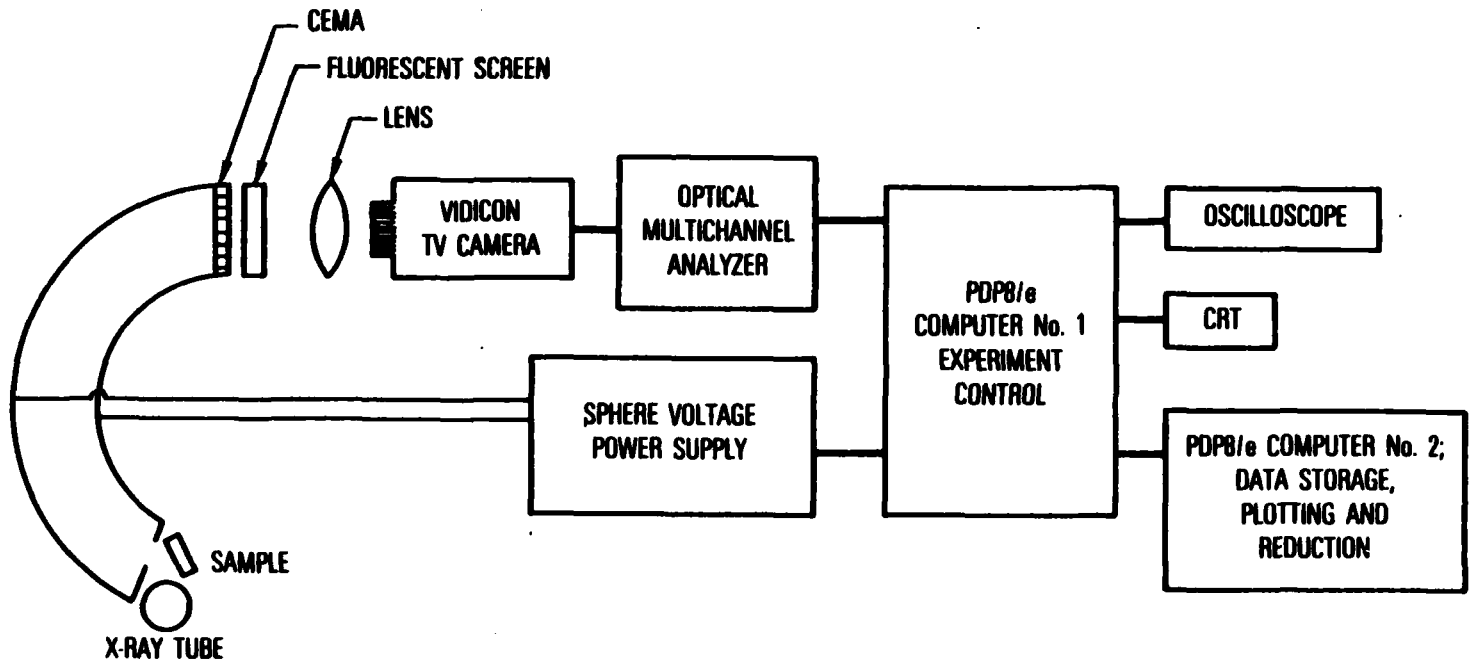


Fig. 1. Schematic Diagram of GCA/McPherson ESCA-36 with Optical Position-Sensitive Detector

has been measured experimentally. This equation neglects fringe-field effects, which are small for the ESCA-36 analyzer geometry.[5]

The single-channel electron multiplier that is standard with the spectrometer was replaced by a channel electron multiplier array (Galileo Electro-Optics Corporation, CEMA No. 6025), which has a gain of up to 10^4 and a spatial resolution of 12 μm. The CEMA is followed by a phosphor screen and a lens system that focuses the optical image on a vidicon TV camera (Princeton Applied Research, No. 1205D). The vidicon has 500 channels that are aligned such that each channel corresponds to electrons exiting the analyzer with an approximately constant energy. The vidicon output is time averaged by an optical multichannel analyzer (Princeton Applied Research, No. 1205A) that is interfaced to the PDP8/e computer that controls spectrometer operation. A schematic diagram of the interface is given in Figure 2.

Extensive software development was necessary to use the new detection system. The program task concerned with analyzer control and data acquisition was rewritten in three sections to utilize the new potential of the instrument. Each of the three sections controls a different possible mode of spectrometer operation: slit mode, one-for-one mode, and snapshot mode (Fig. 3).

In the slit mode, the computer ignores the output from the vidicon except for the central few channels, thus mimicking a single-channel electron multiplier. The number of channels selected for the "slit" can be adjusted, permitting optimization of the trade-off between maximum resolution and maximum count rate. Unlike many x-ray photoelectron spectrometers, the ESCA-36 does not have a retarding field at the analyzer entrance, so the analyzer sphere voltages are stepped in small increments to produce a spectrum, exactly as

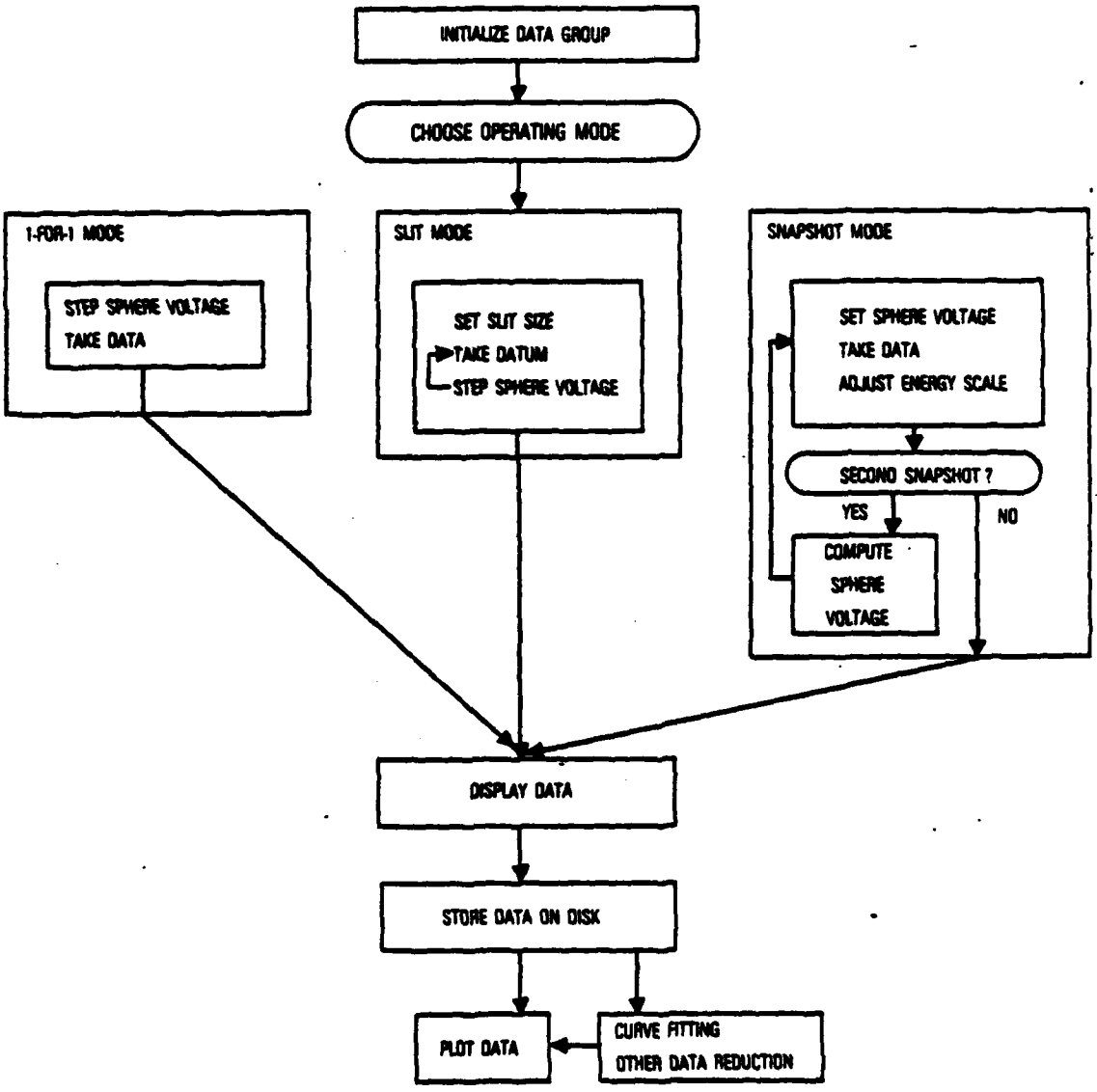


Fig. 2. Flow Diagram of Spectrometer-Control Program

Par 1

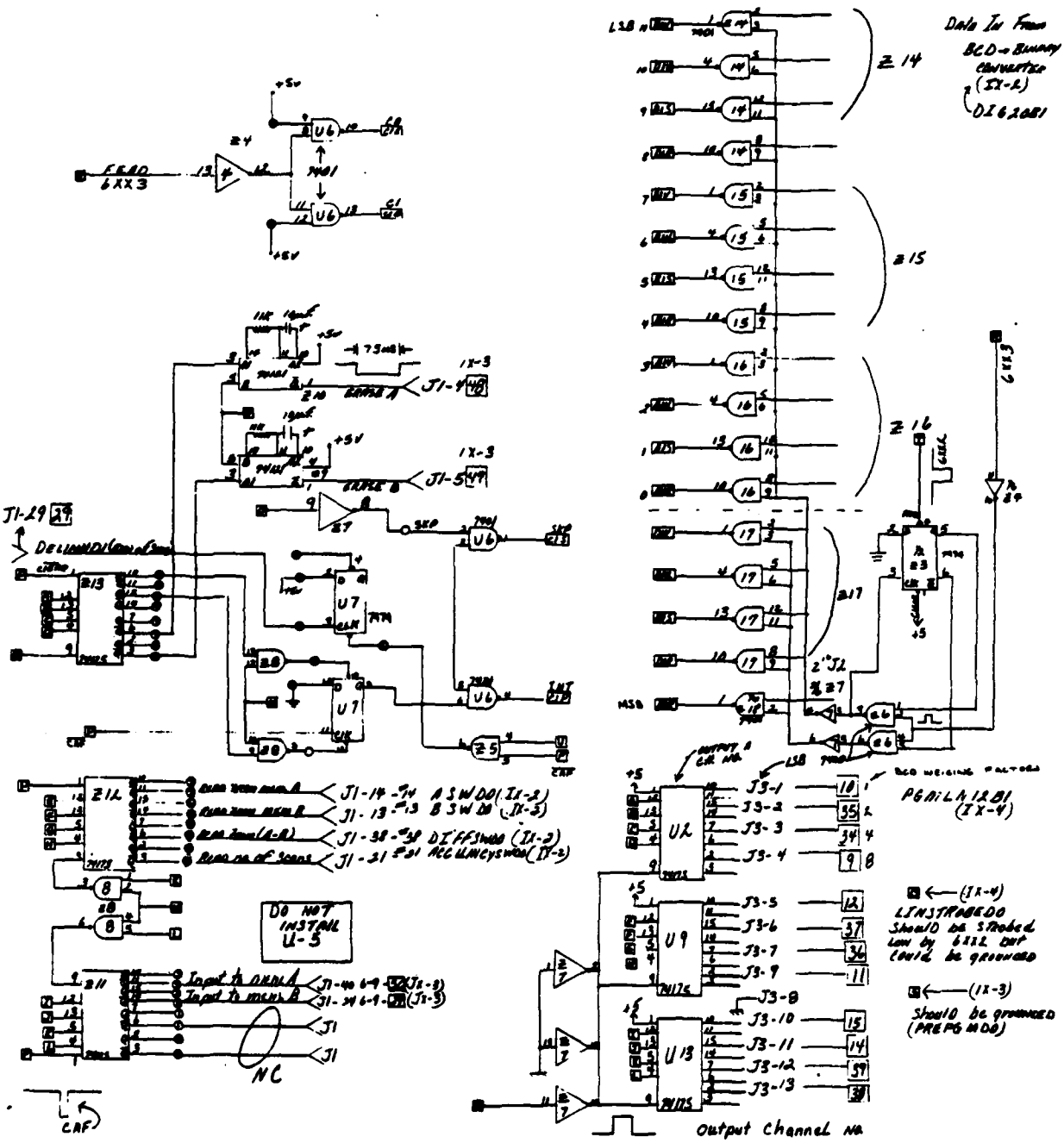


Fig. 3(a). Schematic Diagram of Interface Between Detector and Computer

PART

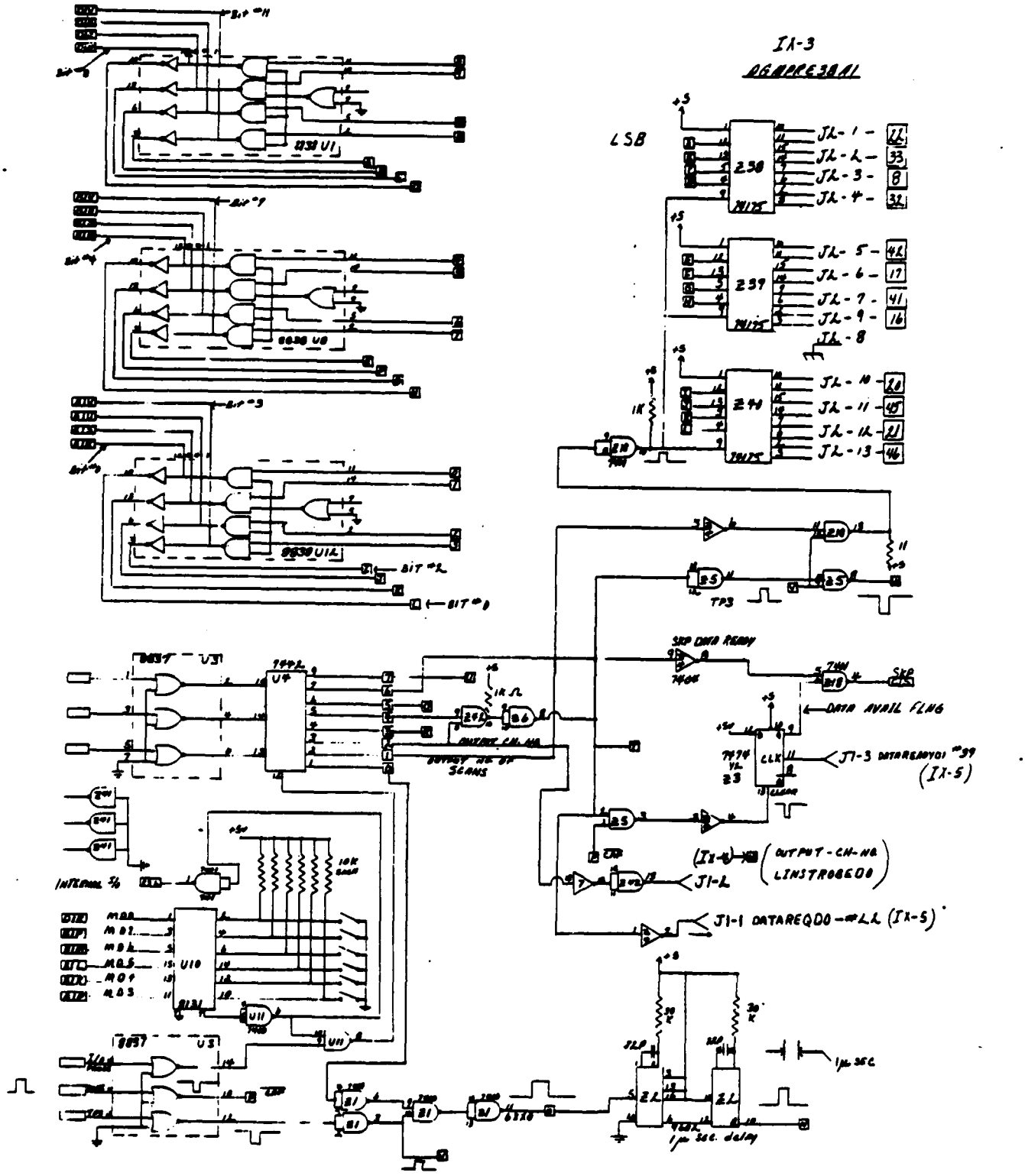


Fig. 3(b). Schematic Diagram of Interface Between Detector and Computer

with a single-channel detector. This mode resulted in no significant speed advantage over the original detector for similar resolution and signal-to-noise ratio.

In the one-for-one mode, the output from each of the 500 channels is simply considered one data point. The display does not have a linear energy scale because the instrument dispersion function is not taken into account. The one-for-one mode was used to determine the dispersion function by measuring the number of channels between peaks whose energy separation (in electron volts) is well known. The dispersion function is fitted to the form

$$\Delta(E) = a\,E + b$$

where $\Delta(E)$ is the energy (in electron volts) per channel, E is the kinetic energy of the electron, and a and b are constants. Thus as the kinetic energy increases, $\Delta(E)$ increases, and a larger energy range is observed in the 500 channels.

The snapshot mode uses all the channels and corrects for the dispersion function. Thus the result is a true XPS spectrum with a linear energy scale; however, the result is obtained much more quickly than in the slit mode. If the specified region of interest is not contained in 500 channels, additional snapshots can be taken with the appropriate sphere voltage settings calculated by the computer to assure matching of the energy scale. The ordinates of adjacent snapshots do not match exactly because the scattered electron background signal is slightly different for each sphere voltage setting.[5] A smooth baseline may be produced by stepping the sphere voltage in increments

of $\Delta(E)$, thus "dragging" the spectrum across the detector. Each successive snapshot is added to the previous total, with the computer adjusting the energies to ensure proper overlap and a linear scale. The method is similar to the slit mode because the sphere voltage is changed by small amounts; however, because all 500 channels of the detector are used, a speed advantage still results.[1,2]

Spectra of Pb and Au taken before and after installation of the position-sensitive detection system are shown in Fig. 4. The analysis times have been adjusted to produce spectra with equivalent signal-to-noise ratio. The new detection system produces spectra in 10 sec that took 45 min to produce using a single-channel detector; this is a factor of about 250 increase in speed. X-ray exposure of samples is much shorter with the new detection system, so more sensitive samples can now be observed. Surface reactions, as well as the progress of x-ray damage and in situ diffusion through thin layers, can be examined if they occur over time spans of at least several minutes.

If speed is sacrificed by using longer data accumulation times, improved sensitivity can be obtained. Very small samples can be analyzed. Typical spectra of a 0.1 cm^2 HgCdTe wafer before and after installation of the position-sensitive detector are shown in Fig. 5. All spectra are unsmoothed. In addition, the sensitivity to surface constituents can be extended to 1% of a monolayer. Thus, the increase in analysis speed provided by the optical position-sensitive detector enables useful measurements to be made where only marginal results or no results were available before.

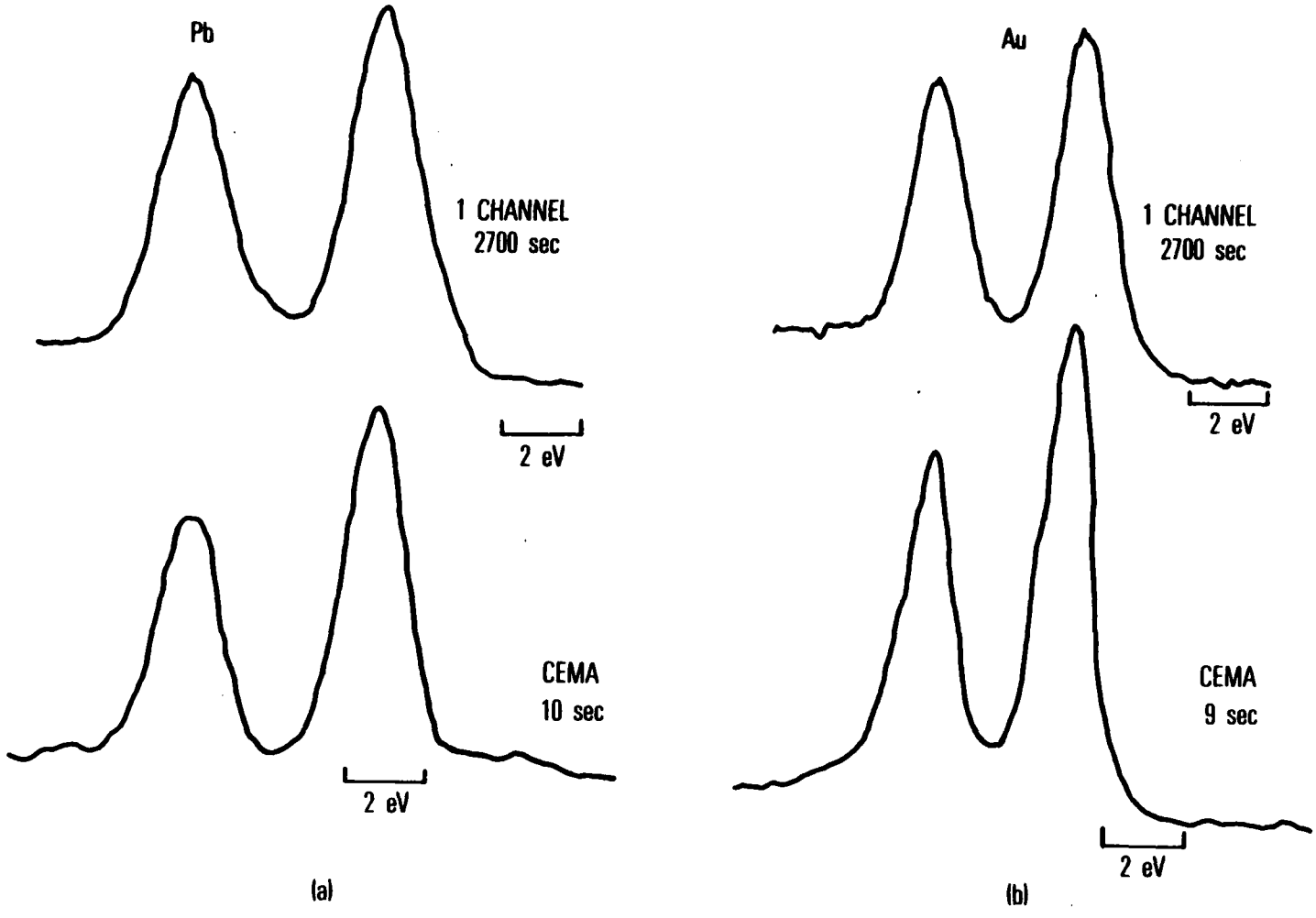


Fig. 4. Spectra with Equivalent Signal-to-Noise Ratio Taken Before and After Installation of Position-Sensitive Detector. (a) Pb. (b) Au

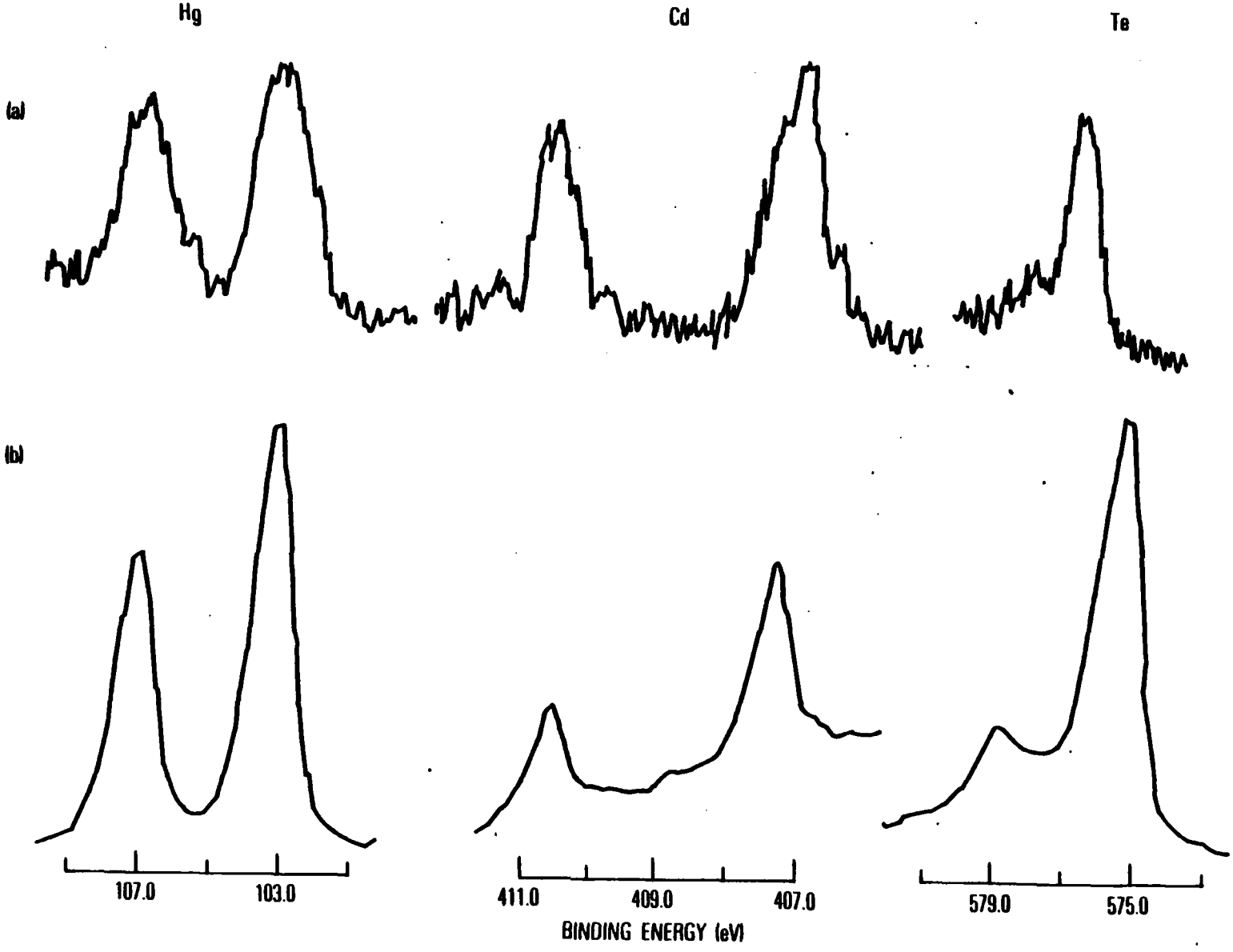


Fig. 5. Typical Spectra of 0.1 cm^{-2} HgCdTe Wafer. (a) Single-channel electron multiplier, 12 min per element. (b) Position-sensitive detector, 2 min per element.

REFERENCES

1. U. Gelius, E. Basilier, S. Svensson, T. Bergmark, and K. Siegbahn, J. Electron Spectrosc. Relat. Phenom. 2, 405 (1973).

2. M. Kudo, Y. Nihei, and H. Kamada, Rev. Sci. Instrum. 49, 756 (1978).

3. H. A. Van Hoof and M. J. Van der Wiel, J. Phys. E: Sci. Instrum. 13, 409 (1980).

4. G. T. Ceasar, J. Weber, and Y. Talmi, Surf. Interf. Anal. 1, 45 (1979).

5. L. M. Chase, Rev. Sci. Instrum. 44, 998 (1973).

LABORATORY OPERATIONS

The Laboratory Operations of The Aerospace Corporation is conducting experimental and theoretical investigations necessary for the evaluation and application of scientific advances to new military space systems. Versatility and flexibility have been developed to a high degree by the laboratory personnel in dealing with the many problems encountered in the nation's rapidly developing space systems. Expertise in the latest scientific developments is vital to the accomplishment of tasks related to these problems. The laboratories that contribute to this research are:

Aerophysics Laboratory: Launch vehicle and reentry aerodynamics and heat transfer, propulsion chemistry and fluid mechanics, structural mechanics, flight dynamics; high-temperature thermomechanics, gas kinetics and radiation; research in environmental chemistry and contamination; cw and pulsed chemical laser development including chemical kinetics, spectroscopy, optical resonators and beam pointing, atmospheric propagation, laser effects and countermeasures.

Chemistry and Physics Laboratory: Atmospheric chemical reactions, atmospheric optics, light scattering, state-specific chemical reactions and radiation transport in rocket plumes, applied laser spectroscopy, laser chemistry, battery electrochemistry, space vacuum and radiation effects on materials, lubrication and surface phenomena, thermionic emission, photosensitive materials and detectors, atomic frequency standards, and bioenvironmental research and monitoring.

Electronics Research Laboratory: Microelectronics, GaAs low-noise and power devices, semiconductor lasers, electromagnetic and optical propagation phenomena, quantum electronics, laser communications, lidar, and electro-optics; communication sciences, applied electronics, semiconductor crystal and device physics, radiometric imaging; millimeter-wave and microwave technology.

Information Sciences Research Office: Program verification, program translation, performance-sensitive system design, distributed architectures for spaceborne computers, fault-tolerant computer systems, artificial intelligence, and microelectronics applications.

Materials Sciences Laboratory: Development of new materials: metal matrix composites, polymers, and new forms of carbon; component failure analysis and reliability; fracture mechanics and stress corrosion; evaluation of materials in space environment; materials performance in space transportation systems; analysis of systems vulnerability and survivability in enemy-induced environments.

Space Sciences Laboratory: Atmospheric and ionospheric physics, radiation from the atmosphere, density and composition of the upper atmosphere, aurorae and airglow; magnetospheric physics, cosmic rays, generation and propagation of plasma waves in the magnetosphere; solar physics, infrared astronomy; the effects of nuclear explosions, magnetic storms, and solar activity on the earth's atmosphere, ionosphere, and magnetosphere; the effects of optical, electromagnetic, and particulate radiations in space on space systems.

FILM